# Fungicide evaluation to rate efficacy to control tuber blight for the Euroblight table
# Results 2009-2011

H.T.A.M. Schepers[1], R. Bain[2], B.J. Nielsen[3], H.G. Spits[1], W. van den Berg[1] & A. Evenhuis[1]

[1] Applied Plant Research, The Netherlands
[2] SAC, United Kingdom
[3] University of Aarhus, Faculty of Agricultural Sciences, Denmark

PPO no. 3250181400

AGV research Unit Arable Farming, Field Production of Vegetables and multifunctional agriculture
June 2012

**These experiments were sponsored by the several Agro Chemical Companies:**

Applied Plant Research (Praktijkonderzoek Plant & Omgeving B.V.)
AGV Research Unit Arable Farming, Field Production of Vegetables and multifunctional agriculture

| | | |
|---|---|---|
| Address | : | Edelhertweg 1, Lelystad, The Netherlands |
| | : | Postbox 430, 8200 AK Lelystad, The Netherlands |
| Tel. | : | +31 320 - 291111 |
| Fax | : | + 31320 - 230479 |
| E-mail | : | info.ppo@wur.nl |
| Internet | : | www.ppo.wur.nl |

# Table of contents

**page**

# Summary

Late blight caused by *Phytophthora infestans* is the most important foliar disease in the cultivation of potatoes. The crop needs to be protected from *P. infestans* by spraying fungicides regularly during the growing season. It is important to use fungicides that effectively protect both leaves and tubers against this disease. Each fungicide has its own mode of action and efficacies and therefore has specific characteristics. To evaluate each characteristic a Euroblight-Table is set up to get an overview of the value of each characteristic. Until now the ratings for the control of tuber blight are based upon expert judgement, both from Agrochemical companies and independent researchers. To evaluate the effectiveness of fungicides harmonised protocols were discussed at Hamar. It was proposed that ratings of fungicides for the EU-table are possible when field experiments are carried out over 2 years in 3 European countries. Field experiments were carried out in Denmark, United Kingdom and the Netherlands in 2009, 2010 and 2011. Thus nine experiments were carried out to compare the effectiveness against tuber blight by measuring the protection of leaves and tubers against infection by late blight caused by application of a fungicide in a standard 7-day spray schedule (this standard spray schedule is not necessarily related to the label recommendations). This protection originates from the protectant and/or curative properties of the active ingredients for leaf blight control. Dose rates were the highest preventative doses registered in Europe. The results of the trials were used to re-evaluate the effectiveness of fungicides to control potato tuber blight. This report describes the analysis of the efficacy of fungicides to control potato tuber blight during the second part of the season. The method to establish efficacy ratings is described and discussed
During the growing season the percentage foliar infection was assessed at least weekly. To evaluate the epidemic, the Area Under the Disease Progress Curve (AUDPC) was determined.
Not all fungicides were tested at every location in each year. REML analysis was conducted to analyse the data, using GENSTAT 14. Based on the average tuber blight incidence (Table 0), ratings for the effectiveness of the fungicides to control tuber blight were calculated, according to formula 0.

$$\mathrm{ER}_k = 5\frac{\mathrm{MAX}(y) - y_k}{\mathrm{MAX}(y)}, \qquad (0)$$

$\mathrm{ER}_k$ = efficacy rating of the fungicide *k* to control tuber blight
y = m_tuber_blight
MAX (y) = m_tuber_blight of the fungicide with the highest tuber blight incidence determined in the series of experiments.

A tuber blight rating was established for five fungicides, Dithane was used as a reference and is considered not effective to control tuber blight.

Table 0. Effectiveness of fungicides to control tuber blight.

| Fungicide | Active ingredient | Dose rate kg or l /ha | StAUDPC[1] | Tuber Blight (%)[1] | Ratings[2] |
|---|---|---|---|---|---|
| Dithane NT | mancozeb | 2.0 | 14.3 | 4.9 | 0.0 |
| Ranman | cyazofamid | 0.5 | 11.9 | 1.2 | 3.8 |
| Ranman + Proxanil | cyazofamid + cymoxanil + propamocarb | 0.5 + 2.0 | 5.8 | 0.4 | 4.6 |
| Canvas + mancozeb | amisulbrom + mancozeb | 0.5 + 2.0 | 10.0 | 1.3 | 3.7 |
| Banjo Forte | dimethomorph + fluazinam | 1.0 | 7.4 | 1.7 | 3.3 |
| Infinito | fluopicolide + propamocarb | 1.6 | 8.4 | 1.1 | 3.9 |
| Mean | | | 10.6 | 2.5 | 2.6 |

[1] : Value established by REML Analysis; back transformed after angular transformation.
[2] : Ratings after angular transformation of tuber blight incidence

In Hamar a more dynamic ratings system for fungicide efficacy in controlling leaf blight was presented. A similar ranking system for tuber blight was proposed. The main advantage is that ratings are determined using a system that is more objective than that used to produce table ratings up until the Hamar meeting in 2008. Another advantage is that there is scope for future, more effective fungicides to be rated higher than 3, the current maximum. Furthermore ratings once given are not fixed, thus relative changes in the effectiveness of fungicides can be made apparent.
These data can and should be used to discuss the procedures in order to establish a final protocol.

# 1 Introduction

Late blight caused by *Phytophthora infestans* is the most important foliar disease in the cultivation of potatoes. The crop needs to be protected from *P. infestans* by spraying fungicides regularly during the growing season. It is important to use fungicides that effectively protect both leaves and tubers against this disease. A whole range of fungicides was or became registered in 2007 and later. Each fungicide has its own mode of action and efficacies and therefore has specific characteristics. To evaluate each characteristic a Euroblight-Table is set up to get an overview of the value of each characteristic. Until now the ratings for the control of tuber blight were based upon expert judgement, both from Agrochemical companies and independent researchers. To evaluate the effectiveness of fungicides harmonised protocols were discussed at Hamar. It was proposed that ratings of fungicides for the EU-table are possible when field experiments are carried out over 2 years in 3 European countries. Three experiments were carried out in 2009 in 3 European countries, and a further three trials in 2010 and 2011, to compare the effectiveness against tuber blight by measuring the protection of leaves and tubers against infection by late blight caused by application of a fungicide in a standard 7-day spray schedule (this standard spray schedule is not necessarily related to the label recommendations). This protection originates from the protectant, curative and antisporulant properties of the active ingredients for leaf blight control in addition to specific protection of tubers. Dose rates were the highest preventative doses registered in Europe. The results of the trials were used to re-evaluate the effectiveness of fungicides to control potato tuber blight. This report describes the analysis of the efficacy of fungicides to control potato tuber blight during the second part of the season. The method to establish efficacy ratings is described and discussed.

# 2 Materials and methods

## 2.1 Trial set up

Experiments were conducted in Denmark, The Netherlands and United Kingdom. Full details are contained in the individual trial reports. Experiments were carried out in 2009 and 2010. The experiments were carried out according to the harmonised protocol as discussed during the Workshops of the "European network on Potato Late Blight in Hamar (2008). The protocol can be found on the Euroblight website (http://www.euroblight.net/EuroBlight.asp) and is presented in Appendix 1.
In general the trials conformed to local good agricultural practice, except the fungicide sprayings against *P. infestans* were carried out as mentioned in Table 1 in a more or less weekly spray schedule. The trials had a minimum of four replicates. The experiments were carried out in accordance with GEP.

## 2.2 Fungicides

In the Netherlands fungicide applications were carried out using a SOSEF-sprayer with Teejet XR110.04 nozzles approximately 50 cm above the foliage. Sprayings were carried out with 250 l/ha.
In Denmark Hardi flat fan (ISO) LD 025 was used. The fungicides were sprayed with pressure of 3.0 bar, at 4.0 km/h and with 300 l water / ha.
In the UK fungicides were applied using a tractor-mounted AZO compressed air sprayer with Lurmark F03-110 nozzles. Fungicides were applied in 200 litres of water per hectare at a pressure of 3.5 bar.
Potato plants were sprayed for the first time at 100 % emergence or when the foliage was meeting along the rows in each experiment. Fungicides were sprayed in a weekly spray schedule, according to protocol. In the first part of the season the experiment was sprayed with mancozeb to control potato late blight in the foliage. The applied dose rate varied between 1.0 kg/ha to 2.25 kg /ha depending on the trial manager. Details are given in the report of each experiment separately. In the UK in 2010 the experiment was sprayed with Curzate M at a dose rate of 2.0 kg/ha.
In the second part of the season specific sprayings to control tuber blight were carried put. The first specific spray was carried out when foliar blight levels were between 0.5% to 5%. Fungicides evaluated are listed in Table 1. If necessary the crop was sprayed full field with Signum or Amistar to control early blight. If needed an extra spray application of mancozeb during the second part of the season was carried out to dampen the foliar blight epidemic.

**Table 1.** Fungicides to control tuber blight sprayed in the experiments in the second part of the season.

| Fungicide | Active ingredient | Dose rate | # Exp.[1] | Company |
|---|---|---|---|---|
| Dithane NT | mancozeb | 2.0 kg /ha | 8 | DOW Agrosciences |
| Ranman | cyazofamid | - | 7 | Belchim Crop Protection |
| Ranman + Proxanil | cyazofamid + cymoxanil + propamocarb | 0.5 + 2.0 | 6 | Belchim Crop Protection |
| Canvas + mancozeb | amisulbrom + mancozeb | 0.5 + 2.0 | 6 | Nufarm |
| Banjo Forte | dimethomorph + fluazinam | 1.0 | 6 | Makhteshim Agan |
| Infinito | fluopicolide + propamocarb | 1.6 | 9 | Bayer Crop Science |

[1] : Indicates the number of experiments in which these fungicides were included in 2009 to 2011.

## 2.3 Experimental conditions

The experimental conditions are presented in Tables 2 and 3. One plant in the spreader rows adjacent to each plot was artificially inoculated with a mixture of *P. infestans* isolates in NL and DK but one isolate of the 13_A2 genotype in the UK. Artificial inoculation was carried out 1 or 2 times depending on the onset of the late blight epidemic (Table 2).

**Table 2**. Experimental conditions at the different locations in 2009.

| | Denmark 2009 | Netherlands 2009 | UK 2009 |
|---|---|---|---|
| Location | Jindevad | Lelystad | Auchincruive Estate, Ayr |
| Soil | | Clay | Sandy Loam |
| Variety | Kardal | Bintje | King Edward |
| Replicates | 4 | 4 | 5 |
| | | | |
| Planting | 6 May | 5 May | 1 June |
| Emergence | 27 May | | - |
| Rotary tillage | | 12 May | - |
| Inoculation | 15 July | 22 July & 7 August | Natural infection from other trials in the same field |
| Haulm killing spreader rows | - | - | - |
| Irrigation | 25 June (27 mm) 10 August (27 mm) | 18 August (10 mm) | None |
| General sprayings Dithane | 18 & 27 June; 1, 8, 15, 22, 29 July; 5 & 12 August | 12, 18, 25 June; 2,9 & 16 July | 8, 15, 25 July; 2 August |
| Specific sprayings July | - | 30 | - |
| Specific sprayings August | 21 & 27 | 10, 17 | 6, 13, 21, 27 |
| Specific sprayings September | 2 & 9 | - | 4 |
| Haulm killing | 17 September | 20 & 27 August | 2 & 11 September |
| Harvest | 19 October | 9 September | 5, 6 & 7 October |
| Tuber blight assessment | 22 October | 11 September | 13, 14, 16 & 17 November |
| Tuber blight assessment | - | 7 October | 1 to 5 & 8 February |

**Table 3**. Experimental conditions at the different locations in 2010.

| | Denmark 2010 | Netherlands 2010 | UK 2010 |
|---|---|---|---|
| Location | Nørregård Flakkebjerg | Lelystad | Auchincruive Estate, Ayr |
| Soil | | Clay | Silty Sandy Loam |
| | | | |
| Variety | Karnico | Bintje | King Edward |
| Replicates | 4 | 4 | 5 |
| Planting | 27 April | 18 May | 24 May |
| Emergence | 1 June | 7 June | 14 June (herbicide) |
| Inoculation | 7 July | 22 July | 13_A2 from neighbouring trials |
| Haulm killing spreader rows | - | - | - |
| Irrigation | 5, 12, 19, 26 July (30 mm) | - | 6 x between 27/8 and 15/9 |
| General sprayings Dithane | 30 June, 7, 14, 23, 26 July, 5 August | 10, 17, 24 June, 2, 8, 15, 23, 30 July, 6 August | 25 August & 1 September |
| General spraying Curzate M | - | - | 8, 15, 23 July, 1 & 9 August |
| Specific sprayings July | - | - | - |
| Specific sprayings August | 16, 23 & 30 August | 18 & 24 August | 16, 24 & 31 August |
| Specific sprayings September | 6 & 14 September | - | 8, 17 & 24 September |
| Haulm killing | 23 September | 31 August | 25 & 30 September |
| Harvest | 18 October | 21 September | 27 October |
| Tuber blight assessment | - | 22 September | 14 December |
| Tuber blight assessment | 15 December | 21 October | 9 March |

**Table 4**. Experimental conditions at the different locations in 2011.

| | Denmark 2011 | Netherlands 2011 | UK 2011 |
|---|---|---|---|
| Location | Nørregård Flakkebjerg | Lelystad | Auchincruive Estate, Ayr |
| Soil | JB 5-6 | Clay | Silty Sandy Loam |
| Variety | Daniella | Bintje | Maris Piper |
| Replicates | 4 | 4 | 4 |
| Planting | 29 April | 12 May | 19 May |
| Emergence | 1 June | ~27 May | Herbicide applied 17 June |
| Inoculation | 6 July | 14 July | From neighbouring trials on unknown dates |
| Haulm killing spreader rows | - | | - |
| Irrigation | | 29 July (5 mm), 19, 25 August (10 m) | None |
| General sprayings Dithane | 29 June, 5, 12, 19 & 27 July | 9, 17, 23, 30 June; 7, 15 & 22[1] July | 6, 13, 20, 27 July, 3, 12, 19, 26[1] August |
| General spraying Curzate M | - | - | - |
| Specific sprayings July | - | 29 | - |
| Specific sprayings August | 3, 13, 18, 24 | 5, 12, 18, 24 | - |
| Specific sprayings September | 1, 9, 16 | - | 1, 8, 15, 23, 30 September |
| Haulm killing | 20 September | 25 August (end of the day) | 7 October |
| Harvest | 25 October | 12 September | 31 October – 2 November |
| Tuber blight assessment | 28 October | 13 September | 2 to 13 December 2011 |
| Tuber blight assessment | 12 December | 18 October | 20 – 28 February 2012 |

[1] Dithane sprayed at a dose rate of 1 kg / ha.

## 2.4 Disease observations

During the growing season the percentage foliar infection was assessed at weekly intervals. To evaluate the epidemic, the Area Under the Disease Progress Curve (AUDPC) was determined. stAUDPC values were calculated by dividing the AUDPC value by the number of days between the first and last disease observation. The number of days from the first to last disease observation varied for each experiment and ranged between 27 and 32 days. The stAUDPC provides an indicator for the efficacy of the fungicides during the whole growing season. Appendix 2 lists stAUDPC values for fungicides tested in each experiment, for each replicate separately.

Tuber blight assessments were made shortly after harvest and after incubation in a non-refrigerated storage. Both number and weight of the potatoes were assessed. Infected tubers were removed at the first assessment. These tubers were counted and weighed. At the end of the incubation period tubers were washed and a second tuber blight assessment was made. In the UK tubers were washed, and dried quickly under ventilation, prior to the first assessment. The number and weight data from both assessments were combined and the percentage tuber blight was calculated.

## 2.5 Statistical analyses

Nine experiments were carried out. Each experiment was laid out as randomised complete block design with one treatment factor, being the fungicides to be tested, and four to five replicates. A mixed model analysis (REML) was performed on stAUDPC and tuber blight incidence based on numbers and weight, measured per experimental plot. Because the measurement period was not equal in all trials stAUDPC was analysed instead of AUDPC. stAUDPC equals the AUDPC divided by the number of days between first and final measurement of disease incidence. The code of the Genstat 14 program (Payne et al., 2009) used for the statistical analysis is in Appendix 3. A mixed model consists of fixed treatment terms (here fungicide) and random block terms (here experiment, block and plot):

$$tuber-blight_{ijkp} = \mu + E_i + B_{ij} + \beta_k + P_{ijp}, \qquad (1)$$

where

$\mu$ = overall mean

$E_i$ = effect of experiment $i \sim N(0, \sigma_E^2)$

$B_{ij}$ = effect of block $j$ within experiment $i \sim N(0, \sigma_B^2)$

$P_{ijp}$ = effect of plot $p$ within block $B_{ij} \sim N(0, \sigma_P^2)$

$\beta_k$ = effect of fungicide $k$

Units with high residuals were determined to establish non – consistent performance of fungicides. The stability of the effectiveness of the fungicides between experiments was evaluated. The mean stAUDPC and tuber blight incidence per fungicide is reported in Appendix 2.
Based on the angular transformed tuber blight incidence (Angn_%_tuber_blight), ratings for the effectiveness of the fungicides to control late blight were calculated, according to formula (2)

$$\mathrm{ER}_k = 5\frac{\mathrm{MAX}(y) - y_k}{\mathrm{MAX}(y)}, \qquad (2)$$

$\mathrm{ER}_k$ = efficacy rating of the fungicide $k$ to control tuber blight during.
y = mn_tuber_blight
MAX (y) = mn_tuber_blight of the fungicide with the highest tuber blight incidence determined in the series of experiments.

The stability of the effectiveness of the fungicides between experiments was evaluated. Arrhythmic means (mn_tuber_blight) of the fungicides performance given as a tuber blight incidence value were calculated. REML Analysis on mn_tuber_blight was carried out. Units with high residuals were determined to establish non – consistent performance of fungicides. REML analysis was used while not each fungicide was present in all experiments. The experiments were conducted in three countries in 2009, 2010 and in 2011. Tuber blight incidence level varied with each experiment. The REML directive takes the specific conditions of the experiment into account. Assume that fungicide A was tested in experiments with a relatively high disease level and fungicide B in experiments with a relatively low disease level. Then the arrhythmic mean of m_tuber_blight of fungicide A would be adjusted with a decrease and fungicide B would be adjusted with a rise of m_tuber_blight. By doing so the tuber blight incidence level for all the fungicides is adjusted to the same level, making a fair comparison between fungicides possible.
The use of stAUDPC as a co-variate to determine the efficacy of the fungicides to control tuber blight was

rejected. The use of a co-variate is only allowed when differences between plots existed prior to the applied treatments. A variable measured afterwards, which may be influenced by the treatments, is not suitable as a co-variate. In fact in that case it is considered a response variate (Oude Voshaar, 1994 [page 54]). In case of stAUDPC it is obvious that it is influenced by the fungicide treatments itself.

**Literature**

Montgomery, D.C. and Peck, E.A., 1982. Introduction to Linear Regression Analysis. John Wiley & Sons. New York.

Oude Voshaar, J.H., 1994. Statistiek voor onderzoekers. Wageningen Press, Wageningen, 253 p.

Payne, R.W., Harding, S.A., Murray, D.A., Soutar, D.M., Baird, D.B., Glaser, A.I., Channing, I.C., Welham, S.J., Gilmour, A.R., Thompson, R., Webster, R., 2009. *The Guide to GenStat Release 12, Part 2: Statistics*. VSN International, Hemel Hempstead.

# 3 Results and discussion

## 3.1 Late blight epidemic

Table 3 shows the start of the potato late bight epidemic in the various field experiments.

**Table 3.** First observation of *P. infestans* infected foliage in the infector plants and in treated plots, during the experiments.

| | Infector plants | | | Treated plots | | |
|---|---|---|---|---|---|---|
| Year | DK | NL | UK | DK | NL | UK |
| 2009 | 27-7 | - | - | 21-8 | 18-7 | 24-7 |
| 2010 | | 13-6 | | 12-8 | 10-8 | 13-8 |
| 2011 | | | | 18-7 | 20-07 | 22-08 |

-: not observed

### 3.1.1 Foliar blight 2009

Late blight occurred at the end of July in The Netherlands and United Kingdom, in 2009. In Denmark the first lesions were found in the second half of August. In The Netherlands and United Kingdom the late blight epidemic developed substantially in August (Figures 1-3).

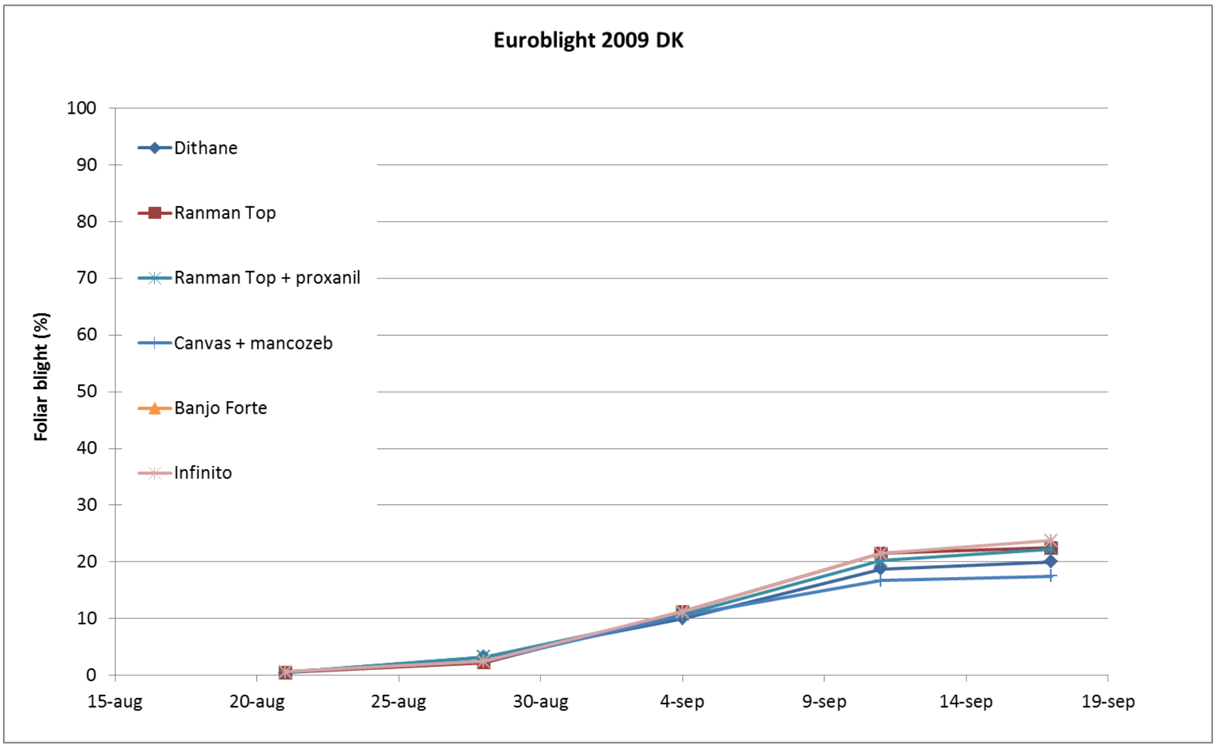


***Figure 1. The development of foliar blight during the growing season in Denmark, 2009. The first specific spraying was carried out on 21 August.***

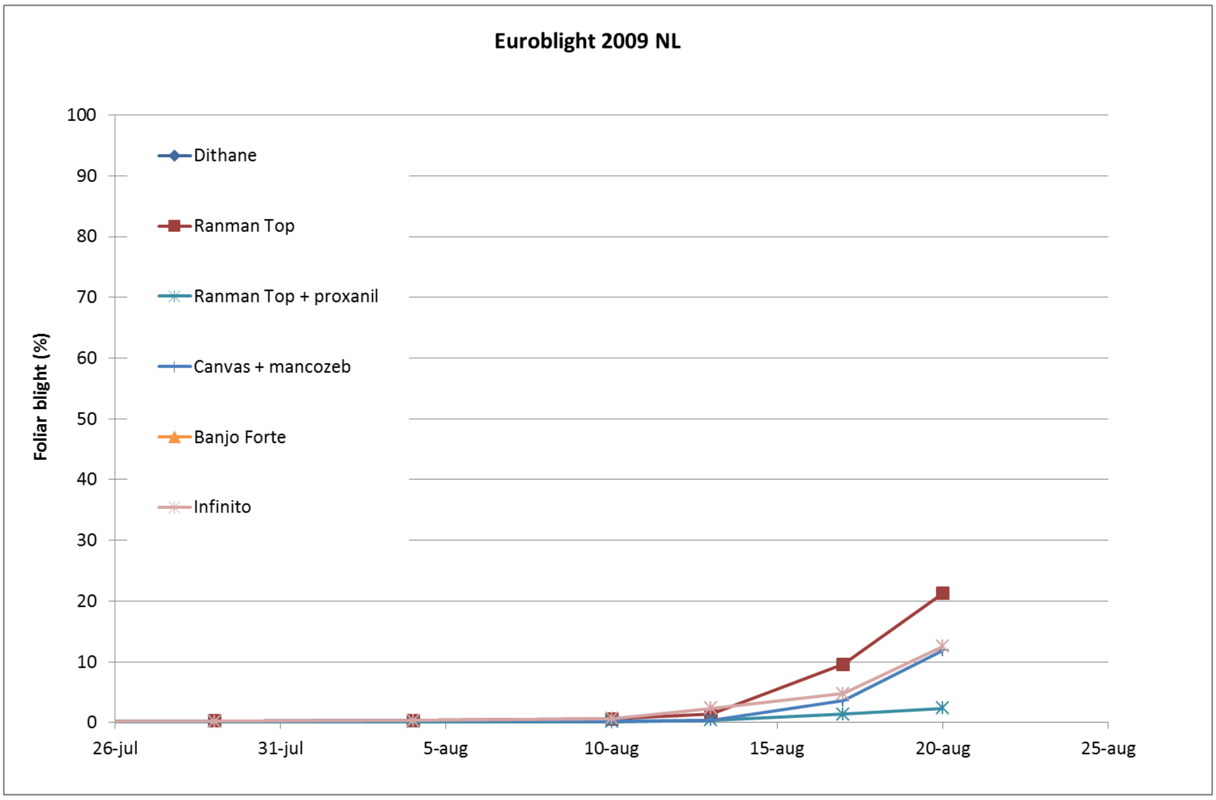


***Figure 2. The development of foliar blight during the growing season in the Netherlands 2009. The first specific spraying was carried out on 30 July.***

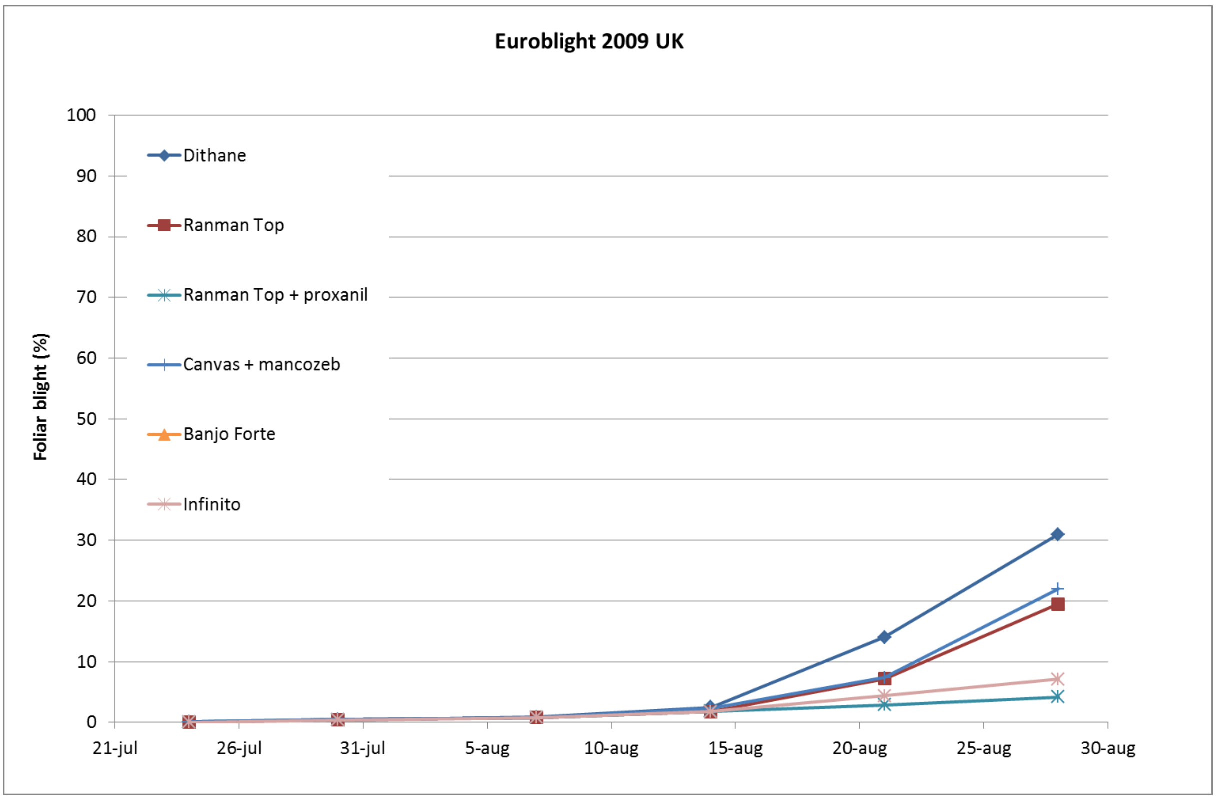


***Figure 3. The development of foliar blight during the growing season in the United Kingdom 2009. The first specific spraying was carried out on 6 August.***

### 3.1.2 Foliar blight 2010

In 2010 the late blight epidemic started in August (Figures 4-6) and developed rapidly.

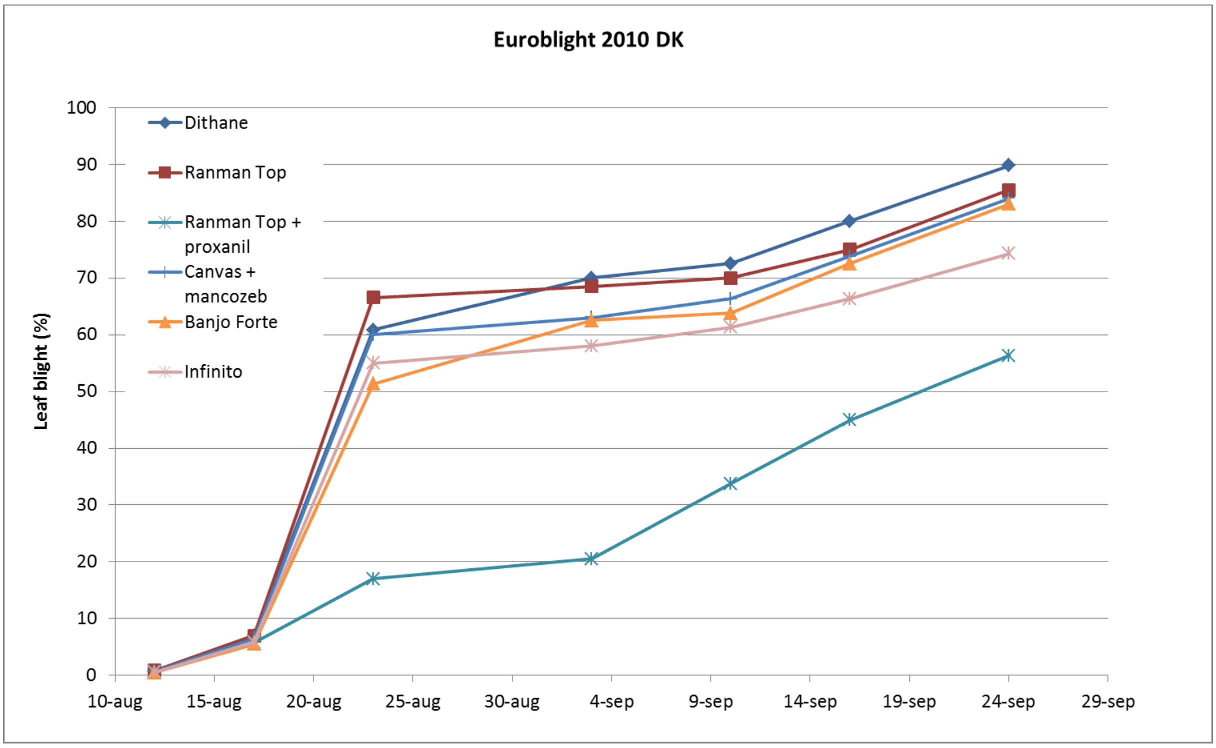


***Figure 4. The development of foliar blight during the growing season in Denmark, 2010. The first specific spraying was carried out on 16 August.***

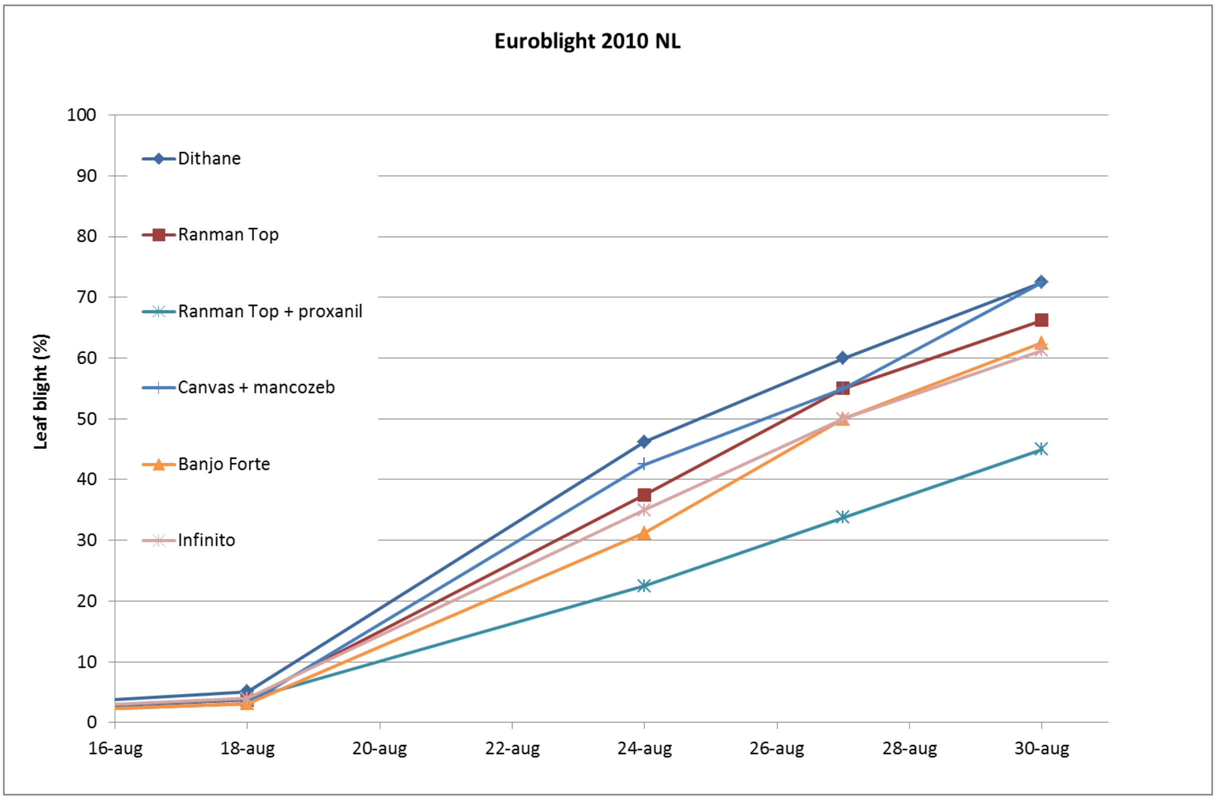


***Figure 5. The development of foliar blight during the growing season in the Netherlands 2010. The first specific spraying was carried out on 18 August.***

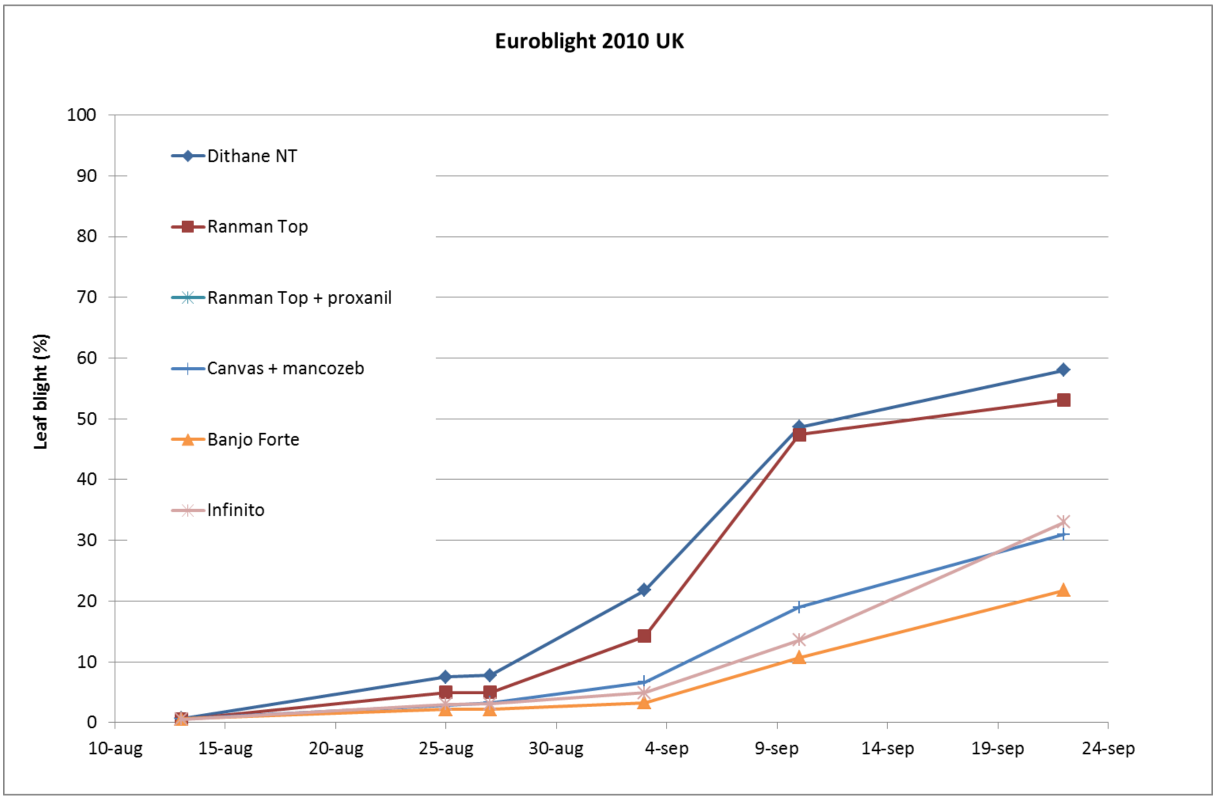


***Figure 6. The development of foliar blight during the growing season in the United Kingdom 2010. The first specific spraying was carried out on 16 August.***

### 3.1.3 Foliar blight 2011

Foliar blight developed progressively from mid-August onwards in the field experiment in Denmark (figure 7) and The Netherlands (Figure 8). In the UK Phytophthora epidemic started from mid-September (figure 9).

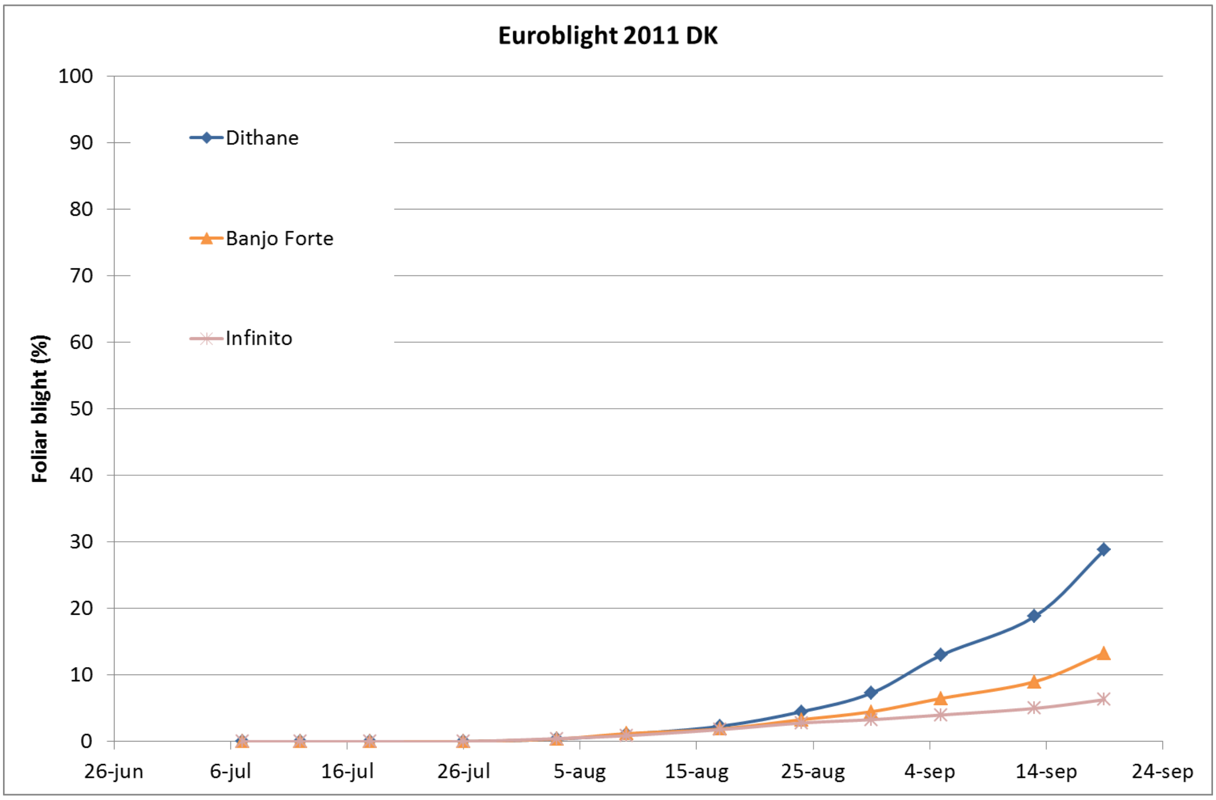


***Figure 7. The development of foliar blight during the growing season in Denmark, 2011. The first specific spraying was carried out on 3 August.***

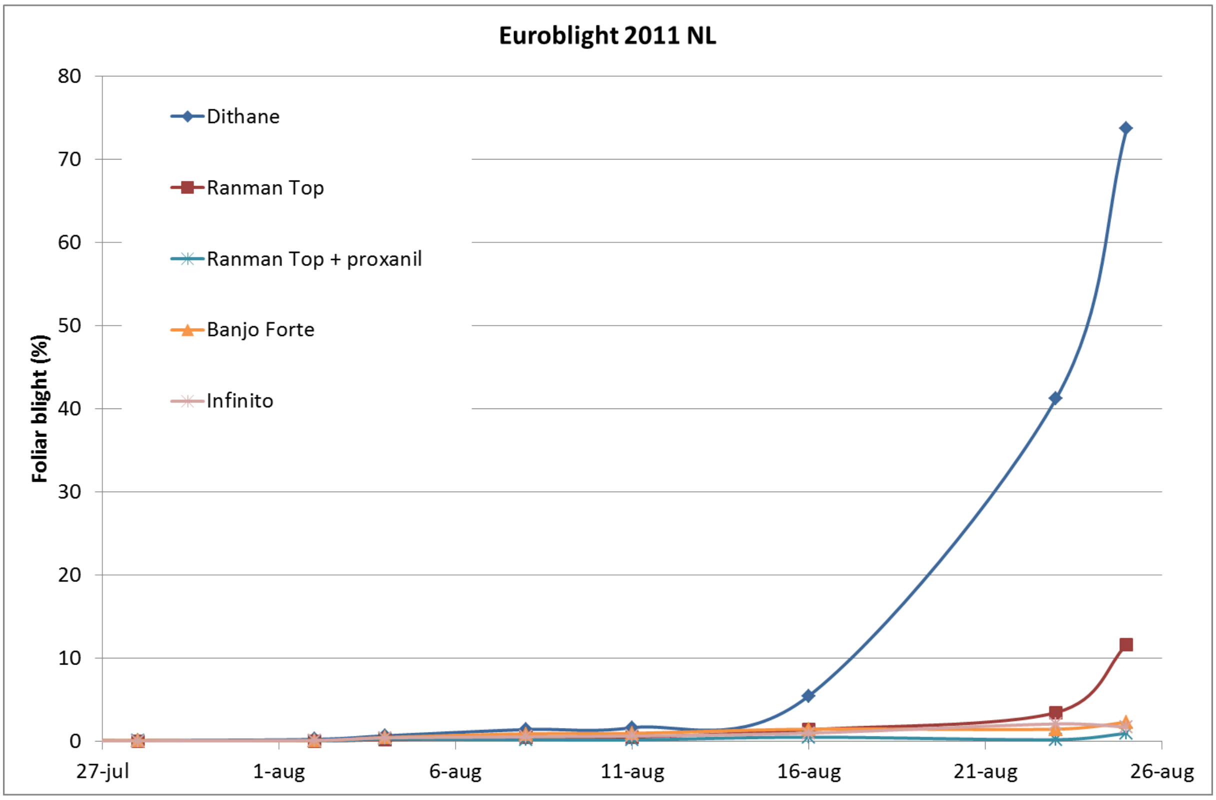


*Figure 8. The development of foliar blight during the growing season in the Netherlands 2011. The first specific spraying was carried out on 5 August.*

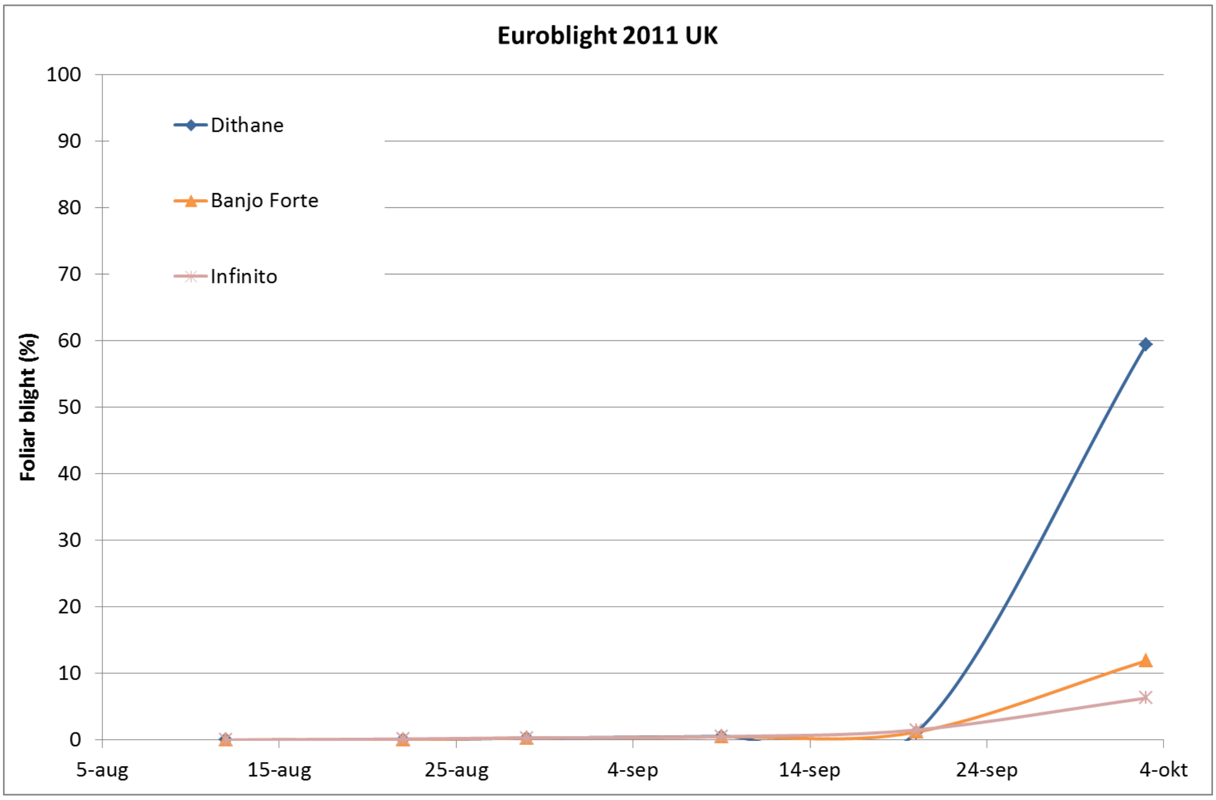


*Figure 9. The development of foliar blight during the growing season in the United Kingdom 2011. The first specific spraying was carried out on 1 September.*

## 3.2 Effectiveness of the fungicides

The AUDPC or the stAUDPC can be used as a measure of the severity of the late blight epidemic. Control of late blight by fungicides will decrease the rate of the epidemic, and therefore reduce the AUDPC and stAUDPC values. Foliar blight levels (Tables 4 & 5) were significantly different between treatments. Details are given in the individual reports per experiment. On average foliar blight was much more severe in 2010 than in 2009. Late blight severity in 2011 varied with the location. The severity of the late blight epidemic partly determines the infection risk of tubers. The infection risk is further determined by precipitation and foremost the efficacy of fungicides to control tuber blight.
Tuber blight levels were low in all three experiments in 2009 ranging from almost 0 to 1.6% (Table 7), nevertheless significant differences between treatments were found within experiments. In Denmark in 2009 the second tuber blight assessment could not be carried out due to frost damage. In 2010 tuber blight levels varied. In 2010 tuber blight incidence was high in The Netherlands, and moderately high in Denmark. Despite abundant foliar blight, tuber blight levels in the UK were low in 2010. Details of the experiments are given in the individual trial reports. In 2011 tuber blight levels were moderately high.

**Table 5.** Effectiveness of the fungicides to control potato late blight as represented by the stAUDPC.

| Fungicide | stAUDPC 2009 | | | stAUDPC 2010 | | |
|---|---|---|---|---|---|---|
| | DK | NL | UK | DK | NL | UK |
| Dithane NT | 10.2 | -[1] | 6.6 | 35.8 | 20.5 | 21.6 |
| Ranman | 11.2 | 2.4 | 4.0 | 35.4 | 17.7 | 19.0 |
| Ranman + Proxanil | 11.0 | 0.4 | 1.6 | 15.6 | 11.4 | - |
| Canvas + mancozeb | 9.4 | 1.1 | 4.4 | 33.3 | 18.7 | 9.3 |
| Banjo Forte | - | - | - | 31.7 | 15.6 | 5.9 |
| Infinito | 11.5 | 1.5 | 2.2 | 30.3 | 16.4 | 8.2 |

[1]: Not included in trial

**Table 6.** Effectiveness of the fungicides to control potato late blight as represented by the stAUDPC.

| Fungicide | stAUDPC 2011 | | |
|---|---|---|---|
| | DK | NL | UK |
| Dithane NT | 8.7 | 8.6 | 9.7 |
| Ranman | - | 1.1 | - |
| Ranman + Proxanil | - | 0.2 | - |
| Canvas + mancozeb | - | - | - |
| Banjo Forte | 4.7 | 0.8 | 2.4 |
| Infinito | 3.0 | 0.7 | 1.5 |

[1]: Not included in trial

**Table 7.** Effectiveness of the fungicides to control potato late blight as represented by tuber blight incidence (%).

| Fungicide | % tuber blight 2009 | | | % tuber blight 2010 | | |
|---|---|---|---|---|---|---|
| | DK | NL | UK | DK | NL | UK |
| Dithane NT | 0.1 | -[1] | 0.6 | 8.5 | 30.4 | 0.0 |
| Ranman | 1.0 | 0.3 | 0.2 | 2.3 | 8.6 | 0.0 |
| Ranman + Proxanil | 0.1 | 0.5 | 0.1 | 2.0 | 3.0 | - |
| Canvas + mancozeb | 0.6 | 0.3 | 0.3 | 1.3 | 10.4 | 0.1 |
| Banjo Forte | - | - | - | 2.3 | 20.8 | 0.2 |
| Infinito | 0.2 | 0.5 | 0.1 | 1.4 | 15.3 | 0.1 |
| Grand Total | 0.3 | 0.7 | 0.5 | 3.7 | 16.9 | 0.1 |

[1]: Not included in trial

**Table 8.** Effectiveness of the fungicides to control potato late blight as represented by tuber blight incidence (%).

| Fungicide | % tuber blight 2011 | | |
|---|---|---|---|
| | DK | NL | UK |
| Dithane NT | 10.3 | 19.9 | 2.6 |
| Ranman | - | 2.3 | - |
| Ranman + Proxanil | - | 0.6 | - |
| Canvas + mancozeb | - | - | - |
| Banjo Forte | 3.3 | 2.8 | 0.3 |
| Infinito | 0.4 | 2.1 | 0.9 |
| Grand Total | 5.3 | 9.4 | 2.1 |

[1]: Not included in trial

## 3.3 Effectiveness of the fungicides to control tuber blight

A new rating system for foliage blight was introduced. A rating system for the control of tuber blight based on the same principles would offer the same benefits. A draft protocol for rating the efficacy of fungicides to control tuber blight season was agreed upon and is presented in Appendix 1.
The efficacies of the fungicides were established (Table 9). Introduction of stAUDPC as a co-variate to determine the efficacy of the fungicides to control tuber blight is statistically not correct. Fungicides can be rated according to formula 2 in which tuber blight incidence was transformed into a decimal rating.

**Table 9.** Effectiveness of fungicides to control tuber blight.

| Fungicide | Active ingredient | Dose rate kg or l /ha | StAUDPC[1] | Tuber Blight (%)[1] | Ratings[2] |
|---|---|---|---|---|---|
| Dithane NT | mancozeb | 2.0 | 14.3 | 4.9 | 0.0 |
| Ranman | cyazofamid | 0.5 | 11.9 | 1.2 | 3.8 |
| Ranman + Proxanil | cyazofamid + cymoxanil + propamocarb | 0.5 + 2.0 | 5.8 | 0.4 | 4.6 |
| Canvas + mancozeb | amisulbrom + mancozeb | 0.5 + 2.0 | 10.0 | 1.3 | 3.7 |
| Banjo Forte | dimethomorph + fluazinam | 1.0 | 7.4 | 1.7 | 3.3 |
| Infinito | fluopicolide + propamocarb | 1.6 | 8.4 | 1.1 | 3.9 |
| Mean | | | 10.6 | 2.5 | 2.6 |

[1] : Value established by REML Analysis; back transformed after angular transformation.
[2] : Ratings after angular transformation of tuber blight incidence

Using formula 2 the minimum rating will be 0, and is given to the fungicide with the highest tuber blight value over all the experiments. A disadvantage of this method is that the fungicide with the highest tuber blight figure might change during the years and thus rated 0.
The highest possible rating is 5. A fungicide can only be rated 5.0 exactly when no late blight occurs in the tubers in any of the experiments. Obviously a rating of 5 is almost impossible to achieve. Even in the 2009 experiments no fungicide was able to prevent tuber blight completely.
The ratings of the fungicides are negatively correlated with the average tuber blight incidence established in the trials. An advantage of the method proposed is that fungicides with a better performance than the fungicides with the highest performance so far can be rated better. Another advantage of the method is that ratings once given are not fixed. With new data a rating could be adjusted to the current performance of the fungicide. However when the database expands changes in the ratings will become rare.

## 3.4 Conclusions

In Hamar a more dynamic ratings system for fungicide efficacy in controlling leaf blight was presented. A similar ranking system for tuber blight is proposed here. The main advantage is that ratings are determined using a system that is more objective than that used to produce table ratings up until the Hamar meeting in 2008. Another advantage is that there is scope for future, more effective fungicides to be rated higher than 3, the current maximum. Furthermore ratings once given are not fixed, thus relative changes in the effectiveness of fungicides can be made apparent.
Since a minimum of 6 experiments in 2 years is required at present a decimal ranking is proposed for nine experimental products and Dithane. These data can and should be used to discuss the procedures in order to establish a final protocol.

# Appendix 1. Harmonised protocol for testing fungicides for effectiveness against tuber blight.

Ruairidh Bain Ruairidh.Bain@sac.co.uk
EUROBLIGHT protocol Version 1.1 Draft 9 January 2009

## Purpose/aim of trials

To compare the efficacy of fungicides in minimizing the incidence of tuber blight through a direct effect, i.e. "activity against tuber infection as a result of fungicide application after infection of the haulm, during mid- to late-season when there is a direct effect on the tuber infection process".
EPPO guideline PP 1/2 (3) (revised in 1996) describes the standard requirements of the field trial.

## Specific requirements

• The trial should use a local potato variety that is susceptible to tuber blight (but not too susceptible to foliar blight) grown as a ware or starch crop. The growth habit of the cultivar should be recorded i.e. determinate or indeterminate growth.
• The trial should have a minimum of four but preferably six replicate plots per treatment. This is to allow for the generally greater variability in tuber blight incidence compared with foliar blight severity. The total plot area per treatment should be 180 m2, i.e. four plots of 45 m2 or six plots of 30 m2, with a minimum of four rows per plot.
• Each treatment consists of a simple fungicide program, starting with blanket sprays of a fungicide with no, or limited, activity against zoospores, e.g. Dithane or Curzate M, applied until there is foliar blight in the fungicide-treated plots. The purpose of the blanket sprays is to allow a slow foliar epidemic with the same amount of foliar blight in each plot. Application of these oversprays should start according to local conditions and applied at intervals judged to be appropriate for a slow epidemic. Application must be before the first infection is seen in the plots.
• Once foliar blight has established in the trial plots, the test fungicides should be applied for the remainder of the growing season until desiccation, regardless of the limited number of applications on the label. A spray interval of 7 (+/-) 1 day is anticipated. The short spray interval should ensure that differences in foliar blight control for the test treatments are as small as possible. It may be necessary to shorten or lengthen the spray intervals to match blight risk. This will be at the discretion of the trial manager. The test fungicides should be applied before foliar blight severity exceeds 0.5% foliar blight. It is anticipated that there will be between three and six applications of the test fungicides.
• It is preferable not to include untreated plots in the trial as these would result in uneven foliar blight gradients.
• Standard treatments can be included in later trials once there is sufficient data to choose the most appropriate standards.
• In order to obtain a long-lasting infection pressure, one or more measures can be used according to local preferences.
• two untreated spreader rows planted between replicates along the complete length of the trial. These should consist of a susceptible (e.g. Bintje) and an intermediate resistant variety.
• spreader rows with one variety and selective fungicide use on the spreader row
• surrounding the trial with maize to increase and maintain a humid microclimate
• Selected individual plants in the spreader rows should be inoculated with P. infestans isolates representative of the local population using recently isolated strains. Record the provenance and genotype characteristics of the strain(s) if known.
• The timing of inoculation should ensure that the test fungicides are not applied until ground cover is close to 100% and progeny tubers are present.
• Misting is permissible when conditions are exceptionally dry and disease is not progressing.
• Irrigation is also permissible if there is insufficient rainfall (at the correct time) to transfer inoculum onto the tubers.

• Record crop cover. Crop cover provides information on how much of the fungicide spray was intercepted by the crop. Crop cover is defined as the percentage of the soil surface obscured by foliage when viewed from above. A grid divided into 20 equal squares allows cover to be assessed to the nearest 5%. Assess by holding the grid at a fixed height above the crop and estimate what percentage of the grid area is filled by leaf material. Assessments should be made at each fungicide application until crop cover reaches 100%. They should also be made if cover declines from 100% towards the end of the growing season.
• Crop growth stage should be recorded at each spray date using the BBCH key.
• The dose rate of each test fungicide should be the highest preventative dose registered in Europe.
• Assess foliar blight every week (or more frequently when necessary) in spreader rows and plots by rating the % infected leaf area. Assess foliar blight using the assessment key in the EPPO-guideline PP 1/2 (3) combined with the key published in Trans. Brit. Mycol. Soc. 31 (1947): 140-141 or the Dutch PD scale guideline. If foliar blight is not uniformly distributed across the plots then its distribution should be recorded.
• Rainfall, air temperature, soil temperature and soil moisture should be recorded.
• Desiccation: The optimum time to desiccate the haulm can be identified if tuber samples are harvested weekly from extra plots of one standard treatment, starting when foliar blight appears in the plots. The tuber samples must be assessed within 24 hours of harvest. These weekly samples will allow changes in the incidence of tuber blight to be monitored.
• A herbicide desiccant should be used. Mechanical destruction of the haulm and sulphuric acid are not permitted.
• The harvest of tubers for the assessment of tuber blight should not take place until the haulm has been dead for a minimum of 3 weeks. However, harvest should not be delayed beyond 5 weeks after complete death of the haulm. Random samples should be taken from the centre rows of each plot for assessment. As a guide, 1600 tubers should be assessed per treatment. The tubers (all > 35 mm) should be thoroughly washed and assessed non-destructively for blight (pre-storage assessment). Any greened tubers should not be assessed. Blighted tubers should be discarded and the rest stored for a minimum of 8 weeks in a non-refrigerated store, after which the tubers are re-assessed (post-storage assessment). At both assessments weights and tuber numbers for blighted tubers and non-blighted tubers should be recorded.
• The tuber blight data should be analyzed using analysis of variance with the foliar blight results included as a covariate.
• Tuber blight ratings will be calculated once there are data from six good trials, over 2 years.

# Appendix 2. Raw data

Plot data of late blight stAUDPC and tuber blight from each experiment in 2009, Denmark:

| Fungicide | Rep. | Country | AUDPC | stAUDPC | n % tuber blight | w % tuber blight |
|---|---|---|---|---|---|---|
| Dithane NT | 1 | DK | 242 | 9.0 | 0.00 | 0.00 |
| Dithane NT | 2 | DK | 235 | 8.7 | 0.00 | 0.00 |
| Dithane NT | 3 | DK | 269 | 10.0 | 0.00 | 0.00 |
| Dithane NT | 4 | DK | 359 | 13.3 | 0.25 | 0.27 |
| Ranman | 1 | DK | 269 | 10.0 | 3.00 | 0.67 |
| Ranman | 2 | DK | 228 | 8.5 | 0.25 | 2.14 |
| Ranman | 3 | DK | 373 | 13.8 | 0.75 | 1.20 |
| Ranman | 4 | DK | 344 | 12.8 | 0.00 | 0.00 |
| Ranman + Proxanil | 1 | DK | 339 | 12.6 | 0.00 | 0.00 |
| Ranman + Proxanil | 2 | DK | 242 | 9.0 | 0.00 | 0.00 |
| Ranman + Proxanil | 3 | DK | 299 | 11.1 | 0.25 | 0.16 |
| Ranman + Proxanil | 4 | DK | 312 | 11.5 | 0.00 | 0.00 |
| Canvas + mancozeb | 1 | DK | 181 | 6.7 | 0.75 | 0.44 |
| Canvas + mancozeb | 2 | DK | 190 | 7.0 | 0.00 | 0.00 |
| Canvas + mancozeb | 3 | DK | 365 | 13.5 | 1.50 | 1.28 |
| Canvas + mancozeb | 4 | DK | 283 | 10.5 | 0.00 | 0.00 |
| Infinito | 1 | DK | 228 | 8.5 | 0.00 | 0.00 |
| Infinito | 2 | DK | 275 | 10.2 | 0.00 | 0.00 |
| Infinito | 3 | DK | 381 | 14.1 | 0.75 | 0.65 |
| Infinito | 4 | DK | 354 | 13.1 | 0.00 | 0.00 |

Plot data of late blight stAUDPC and tuber blight from each experiment in 2009, The Netherlands:

| Fungicide | Rep. | Country | AUDPC | stAUDPC | n % tuber blight | w % tuber blight |
|---|---|---|---|---|---|---|
| Ranman | 1 | NL | 32 | 1.0 | 0.23 | 0.12 |
| Ranman | 2 | NL | 50 | 1.5 | 0.53 | 0.23 |
| Ranman | 3 | NL | 109 | 3.3 | 0.00 | 0.00 |
| Ranman | 4 | NL | 122 | 3.7 | 0.44 | 0.56 |
| Canvas + mancozeb | 1 | NL | 23 | 0.7 | 0.11 | 0.06 |
| Canvas + mancozeb | 2 | NL | 34 | 1.0 | 0.51 | 0.62 |
| Canvas + mancozeb | 3 | NL | 55 | 1.7 | 0.52 | 0.60 |
| Canvas + mancozeb | 4 | NL | 37 | 1.1 | 0.23 | 0.38 |
| Infinito | 1 | NL | 29 | 0.9 | 0.59 | 0.62 |
| Infinito | 2 | NL | 75 | 2.3 | 0.41 | 0.27 |
| Infinito | 3 | NL | 56 | 1.7 | 0.29 | 0.60 |
| Infinito | 4 | NL | 43 | 1.3 | 0.69 | 0.82 |
| Ranman + Proxanil | 1 | NL | 7 | 0.2 | 0.12 | 0.04 |
| Ranman + Proxanil | 2 | NL | 19 | 0.6 | 0.85 | 0.67 |
| Ranman + Proxanil | 3 | NL | 14 | 0.4 | 1.02 | 0.52 |
| Ranman + Proxanil | 4 | NL | 13 | 0.4 | 0.21 | 0.30 |

Plot data of late blight stAUDPC and tuber blight from each experiment in 2009, United Kingdom:

| Fungicide | Rep. | Country | AUDPC | stAUDPC | n % tuber blight | w % tuber blight |
|---|---|---|---|---|---|---|
| Laminator Flo | 4 | UK | 91 | 2.6 | 0.31 | 0.19 |
| Laminator Flo | 3 | UK | 191 | 5.5 | 2.19 | 2.06 |
| Laminator Flo | 1 | UK | 489 | 14.0 | 0.00 | 0.00 |
| Laminator Flo | 2 | UK | 275 | 7.9 | 0.00 | 0.00 |
| Laminator Flo | 5 | UK | 115 | 3.3 | 0.63 | 0.41 |
| Ranman | 2 | UK | 97 | 2.8 | 0.00 | 0.00 |
| Ranman | 4 | UK | 74 | 2.1 | 0.31 | 0.32 |
| Ranman | 1 | UK | 169 | 4.8 | 0.00 | 0.00 |
| Ranman | 3 | UK | 223 | 6.4 | 0.62 | 0.39 |
| Ranman | 5 | UK | 132 | 3.8 | 0.00 | 0.00 |
| Ranman + Proxanil | 4 | UK | 30 | 0.9 | 0.00 | 0.00 |
| Ranman + Proxanil | 5 | UK | 23 | 0.6 | 0.00 | 0.00 |
| Ranman + Proxanil | 3 | UK | 77 | 2.2 | 0.31 | 0.23 |
| Ranman + Proxanil | 1 | UK | 72 | 2.1 | 0.00 | 0.00 |
| Ranman + Proxanil | 2 | UK | 77 | 2.2 | 0.00 | 0.00 |
| Ranman + Proxanil | 4 | UK | 30 | 0.9 | 0.00 | 0.00 |
| Canvas + mancozeb | 1 | UK | 174 | 5.0 | 0.00 | 0.00 |
| Canvas + mancozeb | 2 | UK | 114 | 3.3 | 0.00 | 0.00 |
| Canvas + mancozeb | 3 | UK | 139 | 4.0 | 1.25 | 1.22 |
| Canvas + mancozeb | 4 | UK | 126 | 3.6 | 0.00 | 0.00 |
| Canvas + mancozeb | 5 | UK | 212 | 6.1 | 0.00 | 0.00 |
| Infinito | 3 | UK | 65 | 1.9 | 0.00 | 0.00 |
| Infinito | 1 | UK | 71 | 2.0 | 0.31 | 0.54 |
| Infinito | 2 | UK | 149 | 4.3 | 0.00 | 0.00 |
| Infinito | 5 | UK | 42 | 1.2 | 0.31 | 0.14 |
| Infinito | 4 | UK | 52 | 1.5 | 0.00 | 0.00 |

Plot data of late blight stAUDPC and tuber blight from each experiment in 2010, Denmark:

| Fungicide | Rep. | Country | AUDPC | stAUDPC | n % tuber blight | w % tuber blight |
|---|---|---|---|---|---|---|
| Canvas + mancozeb | 1 | DK | 2307 | 32.0 | 0.00 | 0.00 |
| Canvas + mancozeb | 2 | DK | 2249 | 31.2 | 1.02 | 0.93 |
| Canvas + mancozeb | 3 | DK | 2465 | 34.2 | 1.63 | 1.12 |
| Canvas + mancozeb | 4 | DK | 2570 | 35.7 | 2.62 | 2.43 |
| Ranman | 1 | DK | 2221 | 30.8 | 0.80 | 1.24 |
| Ranman | 2 | DK | 2367 | 32.9 | 1.32 | 1.36 |
| Ranman | 3 | DK | 2612 | 36.3 | 3.50 | 3.15 |
| Ranman | 4 | DK | 2982 | 41.4 | 3.41 | 4.45 |
| Infinito | 1 | DK | 1803 | 25.0 | 0.24 | 0.30 |
| Infinito | 2 | DK | 2041 | 28.3 | 1.42 | 1.75 |
| Infinito | 3 | DK | 2318 | 32.2 | 2.44 | 2.47 |
| Infinito | 4 | DK | 2569 | 35.7 | 1.61 | 2.07 |
| Dithane NT | 1 | DK | 2493 | 34.6 | 5.65 | 5.05 |
| Dithane NT | 2 | DK | 2770 | 38.5 | 3.21 | 3.20 |
| Dithane NT | 3 | DK | 2511 | 34.9 | 14.77 | 5.81 |
| Dithane NT | 4 | DK | 2538 | 35.3 | 10.36 | 10.20 |
| Banjo Forte | 1 | DK | 1882 | 26.1 | 1.33 | 0.93 |
| Banjo Forte | 2 | DK | 2567 | 35.7 | 1.79 | 1.59 |
| Banjo Forte | 3 | DK | 2692 | 37.4 | 3.40 | 3.30 |
| Banjo Forte | 4 | DK | 1995 | 27.7 | 2.49 | 2.63 |
| Ranman + Proxanil | 1 | DK | 1116 | 15.5 | 2.52 | 2.20 |
| Ranman + Proxanil | 2 | DK | 983 | 13.6 | 1.45 | 0.70 |
| Ranman + Proxanil | 3 | DK | 1217 | 16.9 | 2.34 | 2.50 |
| Ranman + Proxanil | 4 | DK | 1174 | 16.3 | 1.51 | 1.11 |

Plot data of late blight stAUDPC and tuber blight from each experiment in 2010, The Netherlands:

| Fungicide | Rep. | Country | AUDPC | stAUDPC | n % tuber blight | w % tuber blight |
|---|---|---|---|---|---|---|
| Banjo Forte | 1 | NL | 470 | 18.1 | 28.55 | 25.47 |
| Banjo Forte | 2 | NL | 367 | 14.1 | 16.41 | 16.85 |
| Banjo Forte | 3 | NL | 419 | 16.1 | 15.67 | 15.68 |
| Banjo Forte | 4 | NL | 370 | 14.2 | 22.43 | 24.66 |
| Canvas + mancozeb | 1 | NL | 508 | 19.5 | 18.76 | 15.81 |
| Canvas + mancozeb | 2 | NL | 498 | 19.1 | 6.54 | 6.77 |
| Canvas + mancozeb | 3 | NL | 498 | 19.1 | 8.96 | 9.11 |
| Canvas + mancozeb | 4 | NL | 445 | 17.1 | 7.44 | 8.49 |
| Ranman | 1 | NL | 593 | 22.8 | 14.60 | 12.49 |
| Ranman | 2 | NL | 352 | 13.5 | 4.67 | 5.20 |
| Ranman | 3 | NL | 396 | 15.2 | 6.02 | 5.29 |
| Ranman | 4 | NL | 498 | 19.1 | 8.92 | 7.88 |
| Ranman + Proxanil | 1 | NL | 443 | 17.0 | 4.70 | 4.49 |
| Ranman + Proxanil | 2 | NL | 220 | 8.5 | 1.96 | 2.11 |
| Ranman + Proxanil | 3 | NL | 288 | 11.1 | 2.29 | 1.72 |
| Ranman + Proxanil | 4 | NL | 239 | 9.2 | 3.24 | 2.98 |
| Infinito | 1 | NL | 473 | 18.2 | 10.00 | 9.70 |
| Infinito | 2 | NL | 348 | 13.4 | 25.64 | 26.38 |
| Infinito | 3 | NL | 501 | 19.3 | 16.01 | 16.24 |
| Infinito | 4 | NL | 389 | 14.9 | 9.64 | 9.00 |
| Dithane NT | 1 | NL | 715 | 27.5 | 34.23 | 31.97 |
| Dithane NT | 2 | NL | 366 | 14.1 | 27.82 | 28.30 |
| Dithane NT | 3 | NL | 576 | 22.2 | 34.04 | 35.76 |
| Dithane NT | 4 | NL | 475 | 18.3 | 25.66 | 26.97 |

Plot data of late blight stAUDPC and tuber blight from each experiment in 2010, United Kingdom:

| Fungicide | Rep. | Country | AUDPC | stAUDPC | n % tuber blight | w % tuber blight |
|---|---|---|---|---|---|---|
| Dithane NT | 1 | UK | 1642 | 33.5 | 0.00 | 0.00 |
| Dithane NT | 3 | UK | 1196 | 24.4 | 0.00 | 0.00 |
| Dithane NT | 2 | UK | 1787 | 36.5 | 0.00 | 0.00 |
| Dithane NT | 4 | UK | 402 | 8.2 | 0.00 | 0.00 |
| Dithane NT | 5 | UK | 260 | 5.3 | 0.21 | 0.12 |
| Ranman | 4 | UK | 903 | 18.4 | 0.00 | 0.00 |
| Ranman | 2 | UK | 1465 | 29.9 | 0.23 | 0.30 |
| Ranman | 3 | UK | 1348 | 27.5 | 0.00 | 0.00 |
| Ranman | 5 | UK | 73 | 1.5 | 0.00 | 0.00 |
| Ranman | 1 | UK | 868 | 17.7 | 0.00 | 0.00 |
| Canvas + mancozeb | 2 | UK | 903 | 18.4 | 0.41 | 0.35 |
| Canvas + mancozeb | 3 | UK | 659 | 13.4 | 0.00 | 0.00 |
| Canvas + mancozeb | 4 | UK | 308 | 6.3 | 0.00 | 0.00 |
| Canvas + mancozeb | 5 | UK | 137 | 2.8 | 0.00 | 0.00 |
| Canvas + mancozeb | 1 | UK | 266 | 5.4 | 0.00 | 0.00 |
| Infinito | 4 | UK | 343 | 7.0 | 0.21 | 0.09 |
| Infinito | 1 | UK | 684 | 14.0 | 0.00 | 0.00 |
| Infinito | 2 | UK | 483 | 9.9 | 0.00 | 0.00 |
| Infinito | 3 | UK | 350 | 7.1 | 0.21 | 0.26 |
| Infinito | 5 | UK | 151 | 3.1 | 0.00 | 0.00 |
| Ranman + Proxanil | 4 | UK | 30 | 0.9 | 0.00 | 0.00 |
| Ranman + Proxanil | 5 | UK | 23 | 0.6 | 0.00 | 0.00 |
| Ranman + Proxanil | 3 | UK | 77 | 2.2 | 0.31 | 0.23 |
| Ranman + Proxanil | 1 | UK | 72 | 2.1 | 0.00 | 0.00 |
| Ranman + Proxanil | 2 | UK | 77 | 2.2 | 0.00 | 0.00 |

Plot data of late blight stAUDPC and tuber blight from each experiment in 2011, Denmark:

| Fungicide | Rep. | Country | AUDPC | stAUDPC | n % tuber blight | w % tuber blight |
|---|---|---|---|---|---|---|
| Dithane NT | 1 | DK | 446 | 9.5 | 9.12 | 9.12 |
| Dithane NT | 2 | DK | 226 | 4.8 | 8.89 | 8.89 |
| Dithane NT | 3 | DK | 484 | 10.3 | 11.87 | 11.87 |
| Dithane NT | 4 | DK | 480 | 10.2 | 11.36 | 11.36 |
| Banjo Forte | 1 | DK | 334 | 7.1 | 4.63 | 4.63 |
| Banjo Forte | 2 | DK | 162 | 3.4 | 3.63 | 3.63 |
| Banjo Forte | 3 | DK | 225 | 4.8 | 3.45 | 3.45 |
| Banjo Forte | 4 | DK | 166 | 3.5 | 1.32 | 1.32 |
| Infinito | 1 | DK | 147 | 3.1 | 0.32 | 0.32 |
| Infinito | 2 | DK | 118 | 2.5 | 0.76 | 0.76 |
| Infinito | 3 | DK | 154 | 3.3 | 0.36 | 0.36 |
| Infinito | 4 | DK | 147 | 3.1 | 0.15 | 0.15 |

Plot data of late blight stAUDPC and tuber blight from each experiment in 2011, The Netherlands:

| Fungicide | Rep. | Country | AUDPC | stAUDPC | n % tuber blight | w % tuber blight |
|---|---|---|---|---|---|---|
| Dithane NT | 1 | NL | 440 | 12.2 | 16.46 | 18.54 |
| Dithane NT | 2 | NL | 253 | 7.0 | 12.44 | 13.39 |
| Dithane NT | 3 | NL | 360 | 10.0 | 21.04 | 23.50 |
| Dithane NT | 4 | NL | 179 | 5.0 | 29.68 | 30.22 |
| Banjo Forte | 1 | NL | 14 | 0.4 | 2.38 | 3.41 |
| Banjo Forte | 2 | NL | - | - | - | - |
| Banjo Forte | 3 | NL | 37 | 1.0 | 2.02 | 2.92 |
| Banjo Forte | 4 | NL | 34 | 1.0 | 4.07 | 4.02 |
| Infinito | 1 | NL | 13 | 0.4 | 2.27 | 2.62 |
| Infinito | 2 | NL | 63 | 1.7 | 3.04 | 3.89 |
| Infinito | 3 | NL | 10 | 0.3 | 1.79 | 1.81 |
| Infinito | 4 | NL | 13 | 0.4 | 1.16 | 2.24 |
| Ranman | 1 | NL | 86 | 2.4 | 3.78 | 3.22 |
| Ranman | 2 | NL | - | - | - | - |
| Ranman | 3 | NL | 23 | 0.7 | 2.50 | 2.52 |
| Ranman | 4 | NL | 14 | 0.4 | 0.60 | 0.36 |
| Ranman + Proxanil | 1 | NL | - | - | - | - |
| Ranman + Proxanil | 2 | NL | 4 | 0.1 | 0.68 | 1.89 |
| Ranman + Proxanil | 3 | NL | 14 | 0.4 | 0.36 | 0.52 |
| Ranman + Proxanil | 4 | NL | 8 | 0.2 | 0.89 | 1.98 |

Plot data of late blight stAUDPC and tuber blight from each experiment in 2011, United Kingdom:

| Fungicide | Rep. | Country | AUDPC | stAUDPC | n % tuber blight | w % tuber blight |
|---|---|---|---|---|---|---|
| Infinito | 1 | UK | 109 | 2.6 | 0.21 | 0.02 |
| Banjo Forte | 2 | UK | 68 | 1.6 | 0.63 | 0.31 |
| Dithane NT | 1 | UK | 428 | 10.2 | 0.83 | 0.61 |
| Banjo Forte | 1 | UK | 69 | 1.6 | 0.00 | 0.00 |
| Dithane NT | 2 | UK | 293 | 7.0 | 3.80 | 3.23 |
| Infinito | 2 | UK | 34 | 0.8 | 0.64 | 0.59 |
| Banjo Forte | 3 | UK | 182 | 4.3 | 0.21 | 0.15 |
| Banjo Forte | 4 | UK | 79 | 1.9 | 0.42 | 0.46 |
| Dithane NT | 4 | UK | 418 | 10.0 | 3.16 | 2.89 |
| Dithane NT | 3 | UK | 493 | 11.7 | 2.53 | 1.67 |
| Infinito | 3 | UK | 48 | 1.1 | 0.63 | 0.16 |
| Infinito | 4 | UK | - | - | 2.11 | 1.96 |

# Appendix 3. REML analysis

```
IMPORT 'W:/PSG/PPO AGV/Tuber blight data.xls'; SHEET = 'data genstat';

TABU [ CLASS = fungicide; PRIN = mean ] weight
SUBSET [ weight .GT. 0; yes ] isave[]

CALC nrmax = NVAL ( AUDPC )
VARI [ VAL = 1 ... #nrmax ] nr

GETA [ ATTR = label ] fungicide; SAVE = save
TEXT [ VAL = #save[] ] label

BLOC Exp / herhaling
TREA expr * fungicide

VCOM [ FIXED = fungicide ] Exp / herhaling

TABU [ CLASS = jaar; PRIN = mean; IP = as ] AUDPC, stAUDPC,
n_%_tuber_blight, w_%_tuber_blight

FOR [ INDEX = i ] y = AUDPC, stAUDPC, n_%_tuber_blight, w_%_tuber_blight; \
  m    = mAUDPC,   mstAUDPC,   mn_%_tuber_blight,   mw_%_tuber_blight; \
  mAng = AngAUDPC, AngstAUDPC, Angn_%_tuber_blight, Angw_%_tuber_blight; \
  mSq  = SqAUDPC,  SqstAUDPC,  Sqn_%_tuber_blight,  Sqw_%_tuber_blight

  IF i .IN. !(3, 4)
    REML [ PRIN = #, mean ] ANGULAR(y); RESI = resi; FITT = fitt
    VKEE fungicide; MEAN = MEAN
    VARI [ VAL = #MEAN ] mAng
    CALC mAng = IANGULAR ( mAng )
    GRAP [ NR = 21; NC = 51 ] resi; fitt
  ENDIF

  REML [ PRIN = #, mean ] y; RESI = resi; FITT = fitt
  VKEE fungicide; MEAN = MEAN
  VARI [ VAL = #MEAN ] m
  GRAP [ NR = 21; NC = 51 ] resi; fitt

  IF i .IN. !(1, 2)
    REML [ PRIN = #, mean ] LOG10(y+1); RESI = resi; FITT = fitt
    VKEE fungicide; MEAN = MEAN
    VARI [ VAL = #MEAN ] mSq
    CALC mSq = 10 ** mSq - 1
    GRAP [ NR = 21; NC = 51 ] resi; fitt
  ENDIF

ENDFOR

PRIN label, mAUDPC, mstAUDPC, mn_%_tuber_blight, mw_%_tuber_blight;  F = 10
PRIN label, SqAUDPC, SqstAUDPC,Angn_%_tuber_blight,Angw_%_tuber_blight; F =
10

DSCA  mAUDPC, mstAUDPC, mn_%_tuber_blight,mw_%_tuber_blight, \
                           Angn_%_tuber_blight, Angw_%_tuber_blight, \
     SqAUDPC,  SqstAUDPC
```

```
GETA [ ATTR = label ] fungicide; SAVE = save
PEN 1; SYMBOL = save[]

DSCA   mAUDPC, mn_%_tuber_blight
DSCA mstAUDPC, mn_%_tuber_blight
DSCA mn_%_tuber_blight, mw_%_tuber_blight

FOR [ INDEX = i ] y = mAUDPC, mstAUDPC, mn_%_tuber_blight,
mw_%_tuber_blight, SqAUDPC,  SqstAUDPC, Angn_%_tuber_blight,
Angw_%_tuber_blight

  CALC y = 5 * ( MAX ( y )  - y ) / MAX ( y )

ENDFOR

CAPTION '0 - 5'; META
PRIN label, mAUDPC,  mstAUDPC,  SqAUDPC, SqstAUDPC; F = 10
PRIN label, mn_%_tuber_blight, mw_%_tuber_blight, Angn_%_tuber_blight,
Angw_%_tuber_blight; F = 10

STOP
```